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Future needs in agricultural meteorology: basic and applied research[1]

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Abstract

Natural resource management and concerns about the quality of the water and air have provided a direct challenge for science to improve our understanding of the environment and the interactions between the practices of man and environmental quality. Challenges in agricultural meteorology research will be directed toward solving environmental and ecological problems, and will contribute toward improving production efficiency. To accomplish this challenge will require both fundamental research directed toward understanding the linkages among the soil–plant–atmosphere components and problem-oriented research to societal issues. There will be a changing paradigm from single investigator projects to an interdisciplinary, integrated research program. Linkage between research and policy decisions will be a major factor in determining the products of the research program. The research needs of several federal, state and private agencies stress the need for improved understanding of the soil plant atmosphere complex, and future agricultural meteorology research should be well-positioned to address these needs.

1. Introduction

The intensive research which has been conducted throughout the United States and the world during the twentieth century has been thought to provide the solution to our current and future problems. However, there always appears to be problems which arise for which the scientific community lacks the answer. Today, there are several challenges which present themselves as new and unique opportunities for creative and imaginative research. Most people would agree that we live in a chan-

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ging world and that there is a constant need for additional information on which we can base our decisions. Agricultural meteorology is in a unique position to help provide the information to address the critical issues of the twenty-first century. These challenges will be outlined and discussed in context with other agricultural disciplines.

2. Holistic science

The division between basic and applied research will continue to be debated within the research community. The recent report of the House Committee on Science, Space and Technology which suggests that if science be examined in terms of its benefit to society it will create some interesting debate in the scientific community as scientists grapple with linking scientific questions with policy issues (EOS, 1992). Congressman George Brown of California is quoted as saying that the current examination of the national science policy "is not intended to diminish the importance of basic research. Research should be linked to a goal-driven process that is relevant to the nation." (EOS, 1992). Questions about the goal of research raised by the House Committee should not be viewed as a condemnation of science, but rather an opportunity to direct and strengthen the current programs. Meyer (1993), in an analysis of future directions of Land Grant Colleges of Agriculture, stated that the missions of the Colleges would have to change to meet the demands of society for research demonstrating the proper use of the natural environment. Land Grant institutions have changed their mission to include topics of human food and fiber systems, agricultural systems, life sciences and technology, environmental quality and natural resources, and human well-being. He challenged organizations to create a vision and an environment for the research programs to address both the short- and long-term responses to societal concerns (Meyer, 1993). These reports suggest that as scientists we need to be aware of the need to link our research to societal needs and also to explain to the public the relevance of our research programs.

Debates over basic and applied research suggest that as scientists we must understand how information is transferred from one scale to the other and the limits of the information. We should view the agricultural system as one in which we conduct research to solve a problem and that the science be viewed as holistic rather than compartmentalized. The greatest challenge will be to determine how the pieces fit together as part of the total picture rather than a series of isolated research pieces. As scientists we must strive toward describing the impact of our research and the linkage of our research with other disciplines. To accomplish this goal will require that we utilize more research planning and integration of agricultural meteorology with other disciplines. In the remainder of this report several examples of the challenges will be provided as a means of stimulating discussions about how we can be more targeted and effective in our research.

There are two major areas in which agricultural meteorology can make an immediate impact and generate guidelines for research past the next decade. These are environmental problems, and food and fiber production. In many instances these

problems could be viewed as the same research program. However, I propose that research problems should be directed toward an understanding of how what we do in agriculture impacts environmental quality, and toward improving production efficiency and product quality. This division also enables us to delineate the linkages with other disciplines.

As part of the holistic complex it is imperative that we also continue to develop a basic understanding of the processes and mechanisms which control the linkages in the soil plant atmosphere complex. The coupling of the energy exchanges between the atmosphere needs to be understood for different surfaces, including natural ecosystems and urban ecosystems, and for both mesoscale and seasonal and yearly time scales.

3. Environmental problems

The United States Environmental Protection Agency (EPA) released a report entitled 'Safeguarding the Future: Credible Science, Credible Decisions', in which several environmental areas that require attention were outlined (EPA, 1992). This report shows how science is used by EPA and discerns areas in which information flow and the knowledge base could be improved. It details how scientific information may be used to impact policy. This report suggests that a closer link should be developed between the problem identification stage and scientific studies and that this linkage continue through the development of policy, regulations and nonregulatory strategies (EPA, 1992). With the impending Clean Water Act and the Clean Air Act being part of the nation's regulations on how we manage our water and air, we need to understand the dynamics of the natural and manmade systems in the context of agricultural practices and environment.

Recent reports by the Agricultural Research Service (ARS) and the Soil Conservation Service (SCS) of the United States Department of Agriculture (USDA) on their research needs provides insights on the environmental science issue (USDA ARS, 1991; USDA–SCS, 1991). Environmental quality is a part of the National Research Initiative program of the USDA Cooperative State Research Service. Identified needs involving agricultural meteorology are as follows.

1. Knowledge of the interactions of wind and water erosion processes on the same site.

2. Information on above and below ground plant biomass at various times during the growing season.

3. Continued research on the effects of various tillage practices, under different soil and climatic conditions, on the movement of sediment and agricultural chemicals into surface and ground water.

4. Methods to estimate the effects of nutrients and agricultural chemicals carried with wind-eroded soil particles on the quality of surface waters and the water quality benefits of wind erosion reduction.

5. A concerted effort by all natural resource scientists to report research findings with complete soil and climatic condition descriptions to ensure maximum transferability to similar environments.

All of these SCS research needs require input from agricultural meteorologists. The last need on the reporting requirements reveals that we will be expected to address the limitations of the research findings and information transfer among sites.

One of the ARS's general research objectives is "To maintain and enhance the quality and productivity of the Nation's soil, water, and air resources through development of new and improved resource management practices and systems and to assess the long-term effects of agricultural activities and environmental changes on the quality and productivity of our natural resources." (USDA-ARS, 1991). The Global Environmental Change Research Program in the ARS has as a general goal to "Develop a comprehensive model for the land-based biosphere component of the Earth system as a means of understanding how both natural and human-induced processes will affect future environmental changes, as well as to provide the basis for designing response strategies that secure the continued productivity and health of the human life-support system." (USDA-ARS, 1991). Several research questions raised in the ARS Research Report that are applicable to agricultural meteorology are listed below (USDA-ARS, 1991).

1. Climate and Hydrologic Systems. This research will relate to how the exchange of water and energy between the land surface and the atmosphere will be affected by changes in land cover---including soil, vegetation and snow—and how climate and land-surface hydrology will interact. Several specific questions which need to be answered are as follows.

(a) Atmospheric warming. How temperature, precipitation, soil moisture and severe weather patterns will be affected in the future by atmospheric warming caused by increased concentrations of greenhouse gases.

(b) Water supplies. How information on the rate and degree of climate change will contribute to our understanding of the future availability of adequate water supplies.

(c) Food security. How understanding of future water supplies, soil moisture and climate will help us anticipate such events as drought, with serious impact on crop yields and world grain supplies.

2. Biogeochemical processes relate to the cycling of carbon and other key elements between the atmosphere and the terrestrial biosphere. Some of the problems to be addressed by this research include the following.

(a) Atmospheric warming. Predicted to increase as a result of increased emissions of atmospheric trace gases.

(b) Stratospheric ozone depletion. Known to be caused by increasing emissions of halocarbons and other trace gases, e.g. nitrous oxide, methane and carbon dioxide.

(c) Deforestation, irrigation and other changes in land use practice. Predicted to affect atmospheric concentrations of radioactively and chemically active trace gases and nutrient balances in terrestrial systems.

3. Ecological systems and dynamics involve interactions between the physical and biogeochemical parts of the global system; models which describe this system must be developed. Some of the basic research questions that must be addressed are as follows.

(a) How do ecosystems affect global climate change? How do ecological processes alter plant water balance, affecting local-to-regional hydrologic balance and the

climate system? How do these processes change vegetation distribution that affects land-surface reflectivity, nutrient cycling, and sources and sinks of greenhouse gases?

(b) How are ecosystems affected by global change? How do changes in climate, atmospheric carbon dioxide concentration, ultraviolet-B radiation, and chemical deposition affect the health and distribution of ecosystems? How do land-use changes such as deforestation alter ecosystem dynamics?

The listed research questions will require approaches at various temporal and spatial scales. These questions will not be answered by one discipline, but will require an integrated, interdisciplinary approach to fully achieve the results desired and a product which is directed toward the problem.

4. Production problems

Production agriculture will continue to be a major emphasis of agricultural research organizations, albeit with increased emphasis on improving production efficiency. This shift of emphasis has been described by Meyer (1993) as a necessary component of the Land Grant College of Agriculture vision of the future. The ARS 6-year plan proposes that research is needed on management systems that provide for sound ecosystem maintenance and efficient water use on important range, pasture and crop lands. There are many aspects in the agricultural production system which require the input of agricultural meteorologists. Many of these problems are related to the efficient use of water.

Efficiency of water use by agricultural systems has been studied intensively in the irrigated areas and is gaining attention in the humid regions as the concern about water quality and water movement through the soil profile continues to grow. The North Central Regional (NCR)-160 Committee on Efficient Use of Water by Vegetation in Great Plains Environments suggested several areas in which there was a need for information on how evaporation could be managed. Several of the recommendations emphasize the need to improve our understanding of the soil water balance under conditions of crop residue management and tillage practices, and that there is a need to conduct long-term coordinated, year-round evaporation studies in key climatic regimes with a range of vegetation and management practices (NCR-160, 1992).

Production problems are better focused on the aspect of sustainability than on production. Agricultural meteorologists can play an important role in the bridge between ecology and agriculture as the focus continues to develop in the area of agroecology. The National Research Council report on 'Sustainable Agriculture: Research and Education in the Field' outlines several examples where agrometeorology has been incorporated into sustainable agriculture research (National Research Council, 1991). The concepts embodied within the sustainable agriculture arena involve the use of a holistic approach to arrive at a solution to a problem and in doing so have incorporated the weather and climatic aspects as production variables. Production problems will become more targeted toward the concepts of sustainability

and we must develop an understanding of the role which weather plays in the production problems and be able to incorporate more of a decision-making framework if we are to provide improved information to farmers.

5. Research needs

This brief examination of some of the problems outlined by the federal agricultural research agencies provides a basis for developing a program of research requirements for agricultural meteorology. The problems that are emerging require two basic components: interdisciplinary research and multiscale research. Interdisciplinary research organizations will evolve to both conduct the research program and the linkage of the research with the policy issues. Researchers will be asked to examine processes at a range of spatial and temporal scales. The USDA global change program shows that it will be necessary to understand the linkage between what happens at the soil surface–atmosphere interface and the impact on global temperature change. Ecosystem dynamics requires that we understand the energy exchange processes at several landscape positions and that this information be applicable to a range of soils and climates.

Bird (1992) described the needs and roles of the Cooperative State Research Service Sustainable Agriculture Research and Education Program. He stressed the need to understand the atmospheric resources. More agricultural meteorologists need to enter into the sustainable agriculture research area and contribute their expertise. There are several specific research needs which I believe we should be addressing.

1. Understanding of the temporal dynamics of the soil surface–atmosphere interface under different surface residue management and tillage conditions for a range of soil, climate and crop regimes.

2. Understanding of the coupling of crop canopy dynamics, crop microclimate, and disease and insect populations. Effective biological or chemical control can be achieved when the population and the driving variables are linked.

3. Evaluating the dynamics of the soil surface–atmosphere interface as related to pesticide volatilization and target application of chemicals.

4. Improved understanding of trace gas dynamics, e.g. methane, nitrous oxide and carbon dioxide, for different soil, crop, atmospheric conditions.

5. Developing improved models of crop and soil dynamics that link with atmospheric changes which can be used to evaluate the potential impact of climatic change.

6. Coupling of the information on seasonal crop water use into a broader understanding of the impact of crop rotations and farm management, e.g. fertilizer and weed control, on water use efficiency in both irrigated and nonirrigated regions.

7. Developing a broader and more thorough understanding of the microscale processes in crop, range and forest canopies in order to understand how changes in the canopy structure are related to changes in the earth's surface, thus impacting global change.

8. Developing a more thorough understanding of the linkages among the processes

of water and wind erosion, and the energy exchanges that occur at the soil surface–atmosphere interface.

9. Improving our understanding of data base technology and information systems in order to improve the transfer of information from the researcher to the user.

6. Discussion

There are many opportunities for agricultural meteorology research for the next decade and beyond. The research emphasis will focus on applying the available information to a range of problems while continuing to build upon areas which have a lack of critical knowledge. Environmental quality and production efficiency problems will require attention to both a basic understanding of the processes and an integration of those processes with other disciplines.

A challenge for the agricultural meteorology educational programs will be to supply adequately trained students who can accept these responsibilities. Agricultural meteorology programs have traditionally been among the most cross-disciplinary in their programs and this has been their strength. I would urge the universities that have agricultural meteorology programs to continue to strive for and develop programs in which students have exposure to a wide range of disciplines and scientific approaches. Agricultural meteorologists, both educators and researchers, are positioned to continue to make very positive contributions to solving important societal problems.

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